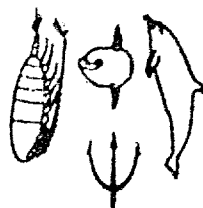


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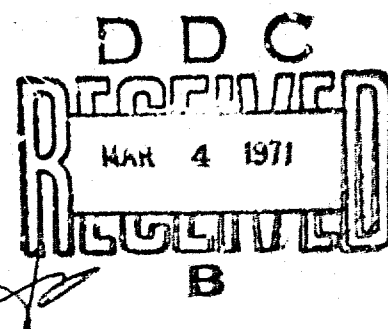


## OCEANIC BIOLOGY

Office of Naval Research



AUGUST 1970



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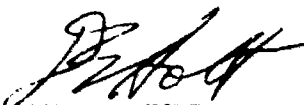
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## FOREWORD

Progress Report Abstracts of the Oceanic Biology Program is presented to a select and limited distribution list in the interest of coordination and communication among investigators being sponsored by this Branch. It is hoped that by this means exchange of scientific information will be stimulated among those having related research interests.

These reports are preliminary in nature and do not constitute publication in the conventional sense. The material referred to herein will ordinarily be published in open scientific literature at a later date. These Abstracts are therefore to be considered as PRIVILEGED PERSONAL COMMUNICATIONS and must not be referred to without the written consent of the researcher and then only as a personal communication.

Credit for this volume belongs to the investigators who conducted the research and supplied the abstracts. We appreciate their cooperation and take pride in the high quality of the research that ONR has the privilege to sponsor.



DEANE E. HOLT  
Program Director  
Oceanic Biology Programs  
Office of Naval Research

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#### MARINE BIOACOUSTICS

This program includes studies on the sound reflection and attenuation caused by the presence of planktonic organisms and members of the nekton. These studies are closely aligned with the sonic devices used by the Navy. Identification of these organisms, their behavior and their geographical distribution is necessary in order to predict their occurrence and to separate them from valid USW targets.

Investigations of soniferous animals are necessary for the proper identification of the sounds produced with the animal source and to predict the occurrence of sounds on the basis of geographical distribution and behavior of the animals. With our expanding knowledge of sound producers in the sea, we will be better able to separate their sounds from others of USW importance in the acoustic ambient. Another major area of programmatic interest is the means by which animals are able to utilize echolocation.

## INVESTIGATIONS ON WHISTLES AND RELATED BIOLOGY OF CETACEANS

David K. Caldwell and Melba C. Caldwell

Marineland Research Laboratory, St. Augustine, Florida, in  
cooperation with the Communication Sciences Laboratory,  
University of Florida

ASSISTED BY Nicholas R. Hall

WORK UNIT NO. NR 104 949

CONTRACT N00014-70-C-0178

### OBJECTIVES

(1) To study the whistles of odontocete cetaceans, especially of the Atlantic bottlenosed dolphin, Tursiops truncatus, with emphasis on their information content; (2) To examine them for age and sex differences; (3) To examine other cetacean phonations potentially capable of carrying information; (4) To gather data relative to the overall biology of Tursiops.

### ABSTRACT

Collection and analysis of whistles of about 100 Tursiops has shown that our earlier hypothesis holds that each individual has a whistle unique to that animal. These recordings have been made of individuals for up to three years under a wide spectrum of conditions from normative swimming behavior to death.

A dolphin was tested to see if he could discriminate between whistles of other dolphins. This he was able to do 100% of the time with less than 1-day training if the whistles lasted as long as .45 seconds. A positive stimulus whistle could be picked 100% correctly from 8 others; recall was 96% correct after 8 months on a test set of two. The subject dolphin has also been able to discriminate two positive signature whistles from a group of 4 stimuli (the 2 positive plus 2 negative).

Pilot studies have been done to study the relationship between level of arousal vs changes within the whistle (e.g., number, rapidity, loudness of emission, etc.). The studies done so far suggest that there is a significant correlation.

An atlas and statistical analysis of Tursiops whistles is well along in preparation. Correlates with age, sex, and effects of acoustic isolation will be presented.

In conjunction with Dr. H. H. Hollien of the University of Florida, studies are under way to examine (by means of X-ray and other techniques used to study human sound production) the mechanisms by which dolphin whistles are produced.

Considerable data have been collected regarding the general biology of the Atlantic bottlenosed dolphin. A study on aging, conducted in cooperation with Dr. David E. Sergeant of the Fisheries Research Board of



Canada, is virtually complete.

#### PLANS FOR FUTURE

Studies on the whistles will be continued until all obvious channels are explored (especially further discrimination studies using a wide spectrum of stimuli--including whistles made by dolphins of other genera as well as Tursiops of varying sizes, sexes and numbers). The atlas will be completed shortly, but will be supplemented periodically as new subjects become available. The information components of the whistle will be studied not only by testing animals using partial natural whistles, but also by testing with artificially-produced whistles similar to natural ones which can better be controlled for this purpose. Sound localization studies, using dolphin sounds and human subjects, will be done in cooperation with Dr. Hollien. The relationships of stress to whistling will be given special attention. The biology of Tursiops will be studied in increasing detail as opportunities permit and should be advanced greatly with planned studies on wild schools--both from an acoustic and behavioral standpoint.

#### CURRENT REPORTS AND PUBLICATIONS

- (a) D. K. Caldwell, M. C. Caldwell and J. F. Miller (1969), "Three brief narrow-band sound emissions by a captive male Risso's dolphin, Grampus griseus". Bull. So. Calif. Acad. Sci., 68: 252-256.
- (b) M. C. Caldwell and D. L. Caldwell (1970), "Etiology of the chirp sounds emitted by the Atlantic bottlenosed dolphin: a controversial issue." Underwater Nat., 6(3): 6-8, 43.
- (c) M. C. Caldwell, D. K. Caldwell and N. R. Hall (1969), "An experimental demonstration of the ability of the Atlantic bottlenosed dolphin to discriminate between whistles of other individuals of the same species. Tech. Rept. 6, Los Angeles County Mus. Nat. Hist. Found., ONR/MRL contract N00014-67-C-0358.
- (d) M. C. Caldwell, D. K. Caldwell and J. F. Miller (1970), "Statistical evidence for individual signature whistles in the spotted dolphin, Stenella plagiodon. Tech. Rept. 7, Los Angeles County Mus. Nat. Hist. Found., ONR/MRL contract N00014-67-C-0358.
- (e) M. C. Caldwell, D. K. Caldwell and R. H. Turner (1970), "Statistical analysis of the signature whistle of an Atlantic bottlenosed dolphin with correlations between vocal changes and level of arousal. Tech. Rept. 8, Los Angeles County Mus. Nat. Hist. Found., ONR/MRL contract N00014-67-C-0358.
- (f) M. C. Caldwell and D. K. Caldwell (1970), "Statistical evidence for individual signature whistles in Pacific whitesided dolphins, Lagenorhynchus obliquidens. Tech. Rept. 9, Los Angeles County Mus. Nat. Hist. Found., ONR/MRL contract N00014-67-C-0358.

## **STUDY OF SOUND SCATTERING IN THE OCEAN**

**Wm. D. Clarke**

**Westinghouse Ocean Research Laboratory**

**ASSISTED BY T.P. Barnett, A. Kirst, A. Nelkin, R.J. Rosenthal and  
D.D. Skinner**

**WORK UNIT NO. NR**

**CONTRACT N00014-68-C-0366**

### **OBJECTIVES**

(a) To field test and calibrate a multifrequency sonar array with its associated environmental sensors and data logging systems, (b) to make field measurements with the sonar array of sound scattering in the upper 1000 m of the ocean, (c) to obtain biological collections in the same region with a variety of gear for determining the distributions of organisms relative to sound scattering, and (d) to compare distributions of organisms obtained by visual observations from a submersible and from a towed high-frequency side-looking sonar with distributional information gathered by the sonar array and biological collecting gear.

### **ABSTRACT**

A multi-frequency sonar array has been designed, assembled and field tested. The six transducers of the sonar array operate at the following frequencies; 3.5 KHz, 12 KHz, 20 KHz, 40 KHz, 60 KHz, and 150 KHz. The sound output of each transducer is focused into a beam either by a reflector or acoustic lens. Gating of the listening period for returns from each sound burst of a transducer delimits the volume of water insonified for back scattering measurements. Thus, known volumes of water can be insonified by the sonar array for the purpose of comparing sound scattering at different frequencies.

The transducers along with their reflectors and acoustic lenses are mounted in a supporting frame which is capable of rotation through 360° of arc. The sonar array during rotation sweeps in a horizontal path the volume of water surrounding it in much the same manner as a radar. By raising and lowering the sonar array profiles of sound scattering at six different frequencies can be made in the upper 1000 m of the ocean. The sonar array is also equipped with several sensors which monitor the depth of the array, its direction of orientation in the horizontal plane during operation at depth, the water temperature and the ambient light level.

### **PLANS FOR FUTURE**

(a) To conduct a multi-ship operation investigating the distribution of organisms and sound scatterers in the upper 1000 m of the ocean using the sonar array, a variety of trawls and nets, a submersible for direct visual observations of organisms that are potential sound scatterers, and a towed high-frequency (150 KHz) side-looking sonar to investigate the distributions of sound scatterers over large-scale horizontal distances, (b) to analyze and compare the measurements made by these different techniques for a better understanding of sound scattering particularly as it applies

to the migrating sonic scattering layers, and (c) to ascertain the numbers of sound scatterers per unit volume of water and their dependence on frequency.

#### CURRENT REPORTS AND PUBLICATIONS

(a) R. H. Backus, J. E. Craddock, R. L. Hedrich, D. L. Shores, J. M. Teal, A. S. Wing, G. W. Mead and W. D. Clarke (1968), "Ceratoscopelus maderensis: peculiar sound-scattering layer identified with this myctophid fish." Science 160 (3831): 991-993.

**OBSERVATIONS OF FREE-SWIMMING PORPOISE AND WHALE SCHOOLS AND  
STUDIES OF THE CHEMISTRY OF HEAD OIL IN PORPOISES**

**Kenneth S. Norris, Oceanic Institute  
Donald C. Malins, Food Science Pioneer Research Laboratory**

**ASSISTED BY Thomas Dohl and U. Varanasi**

**WORK UNIT NO. NR 104-837/11-10-69  
Code 484**

**CONTRACT N00014-70-C-0258**

**OBJECTIVES**

(a) To study the daily behavior and natural history of a wild porpoise school, and (b) to study the chemical characteristics of lipids in the fat tracts of the porpoise head in order to determine whether or not this sonically active tissue might have special features.

**ABSTRACT**

(a) A unique situation has been found in which it is possible to learn many details of the lives of wild porpoises. These animals, a school of about 60 spinner porpoises (Stenella roseiventris) come daily into Kealahou Bay, Hawaii, and spend up to 10 hours in very calm waters, often within a few yards of a sheer cliff base. Observations are being made from a camp established at the cliff edge, 500 feet above the water, and from a subsurface observation craft, the MOC, amongst the animals. Overflights have been made to determine the distribution of other schools and their movements offshore. A regular daily activity cycle has been observed in which animals enter the bay in the morning, apparently coming in later if the moon was bright the evening before, and earlier if there was no moon or a moon early in the morning. The animals enter in a broad rank, showing marked subschool structure, jumping and "spinning." They subside into a quiescent period which probably represents sleep in which a tightly packed discoidal school is formed. Aerial behavior ceases and dive times increase markedly. Then awakening occurs with a burst of aerial behavior. The school moves back and forth and finally takes a bearing and moves out to sea late in the afternoon. Feeding is apparently at night as afternoon animals have empty stomachs while morning ones contain undigested food.

Schools are regularly spaced around the island, and are apparently discrete. Twenty-eight animals are known by scars and marks and many have been seen repeatedly. Details of social behavior and school structure are emerging, as are seasonal reproductive cycles and other data.

(b) Studies of the biochemistry of lipids found in the fatty channels of the porpoise head have been carried out using several species. Lipid accumulations in these areas, which consist of the fatty melon or forehead, and discrete channels

of fat both inside and outside the lower jaws, communicating with the tympanic bulla, have been traced and investigated by a variety of biochemical methods. The lipids which are unique wax esters have been found to be unique in structure. Whether these lipids are acoustically active in some fashion is under investigation. Sound propagation velocity has been found to vary in a regular fashion throughout the melon and in such a manner that sound emanating from the nasal plug will be focused into a discrete beam, a feature known to exist in porpoises.

#### PLANS FOR FUTURE

(a) Studies of the porpoise school are entering three new phases. First, radio tracking will be used to follow porpoises at night, to supplement the few visual observations we have been able to make at this time. Second, acoustical studies are beginning in which we will monitor and study the various sound emissions of the animals throughout day and night, to see what correlations with behavior can be noted, and third, studies of adjacent schools will be made to ascertain if mixing occurs and when.

(b) Further work is being conducted on porpoise lipids to determine micro-distribution of biochemical changes within the porpoise head and to learn further about variations within the odontocete whales.

#### CURRENT REPORTS AND PUBLICATIONS

(a) U. Varanasi and D. C. Malins, "Alkyl ethers of diols and glycerol from mandible lipid of a porpoise (Phocoena phocoena)," Oceanic Institute Contribution No. 61, submitted to Biochemistry, April 1970.

(b) D. C. Malins and U. Varanasi, paper on unusual lipid of the porpoise mandibular canal, Oceanic Institute Contribution No. 68, in preparation.

TELEMETERED ANALYSES OF PINNIPED  
PHYSIOLOGY AND ACOUSTICS

Carleton Ray  
The Johns Hopkins University  
Baltimore, Maryland 21205

ASSISTED BY S.R. Harmon, and J. Parker

WORK UNIT NO. NR 104--097/11-6-68(484) CONTRACT N00014-67-A-0163-  
0004

OBJECTIVES

(a) To develop, test, and utilize in the field, telemetric equipment for pinniped acoustics and physiology related to behavior, (b) to perform operant conditioning tests in the laboratory on phocid sensory systems, (c) to conduct correlated field studies on the behavior of phocid seals.

ABSTRACT

This is the second year of our program. Our objectives involve operant conditioning studies in our aquatic facility, development of telemetric equipment, and field studies as follows:

(a) Operant conditioning studies. The purpose has been to develop criteria for visual size discrimination for use as a tool in the elucidation of visual cues to underwater orientation. We have chosen size discrimination for ease of operant conditioning. The first phase of studies on the spotted seal, Phoca vitulina largha, has shown 95% accuracy in detecting 1 cm. differences in targets of 2-15 cm. diameter at a distance of 8 feet.

(b) Telemetry. Three instruments are in hand and ready for initial testing: (1) a radioendosonde for the recording of internal body temperature, (2) a radioexosonde for the recording of external body temperature, and (3) a recording instrument package (RIP) to be worn by a seal (or a human diver) and which will record on tape both internal and external temperatures for at least hour-long dives.

(c) Field Studies. A field trip for the month of May in Gambell, Alaska (Bering Sea) will continue both behavioral and acoustic/physiologic observations. Fortunately, added support for this trip has been given by The U.S. Navy, Naval Ships Systems Command (Supervisor of Diving), and the General Electric Company, both of whom wish to utilize our expedition to test the Mark X, Mod 0 closed-circuit scuba. This will be used under and around ice to investigate pinniped environments. Its use in an eskimo village will comprise a

rigorous field test of the equipment. Fortunately as well, C.B.S. News also will support the expedition for the purpose of documenting our activities for television in the "Adventure" series. Their support will yield a film and sound record of the entire expedition, including behavioral data.

#### PLANS FOR FUTURE

As this was a three-year program, but is apparently to end in year two due to budgetary and policy changes within ONR, plans are somewhat in a state of flux. However, we will continue to apply the tool of visual size discrimination to problems of orientation under various light levels and wave lengths. Telemetric devices will aid in studies of thermoregulation of seals. The RIP particularly could prove of value in the study of both seals and man. Man-in-the-sea is seriously impeded due to cold water temperatures of most seas. The RIP's ability to record surface and internal temperatures should prove of direct value in the evaluation of heated suits and other devices as well as revealing features of man's underwater thermoregulatory physiology. It would be important to contrast man's ability in this respect with that of a marine mammal and the latter remains our initial task.

How able we will be to continue in all aspects of research depends obviously upon funding.

#### CURRENT REPORTS AND PUBLICATIONS

(a) Carleton Ray, (1970) Population ecology of Antarctic seals. For second SCAR Biology Symposium, Ed. M.W. Holdgate, Academic Press, London and New York

(b) Carleton Ray, W. A. Watkins and John J. Burns, (Summer 1969), "The Underwater song of Erignathus (bearded seal). Zoologica, 54 (2): 79-83 - Phonograph disc

(c) William E. Schevill, William A. Watkins, and Carleton Ray, (1969) Click structure in the porpoise, Phocoena phocoena. Jour. Mammalogy, 50 (4): 721-728

(d) Carleton Ray and S.R. Harmon ( in preparation for Communications in Behavioral Biology) "Visual size discrimination in the Spotted seal, Phoca sistrina largha".

(e) Carleton Ray and S.R. Harmon ( in preparation for Communications in Behavioral Biology) "A self-contained tank for maintenance and observation of marine mammals".

## MARINE BIOACOUSTICS AND BIO-ORIENTATION

Howard E. Winn  
University of Rhode Island  
Kingston, Rhode Island

**ASSISTED BY** J. Fish, W. Richkus, R. Edel, D. Morgan

**WORK UNIT NO. NR**

**CONTRACT** N00014-68-A-0215-0003

### OBJECTIVES

(a) To study daily movements, sounds and behavior, response to sound playbacks, and distribution of sound producing animals at sea of pilot whales, humpback whales and white whales (beluga), (b) to study communication signals of the white whale in captivity (c) to understand the complete bioacoustic system of the toadfish (d) to elucidate the cues that determine the migratory pathways of alewives (a fish), american eels and parrot fish.

### ABSTRACT

Sounds and the movements of pilot whales and humpback whales have been recorded over 24 hours. The relation of the patterned cry and other sounds to certain behaviors have been determined. Playback has resulted in modifying their behavior under certain conditions. The distribution of calling single individuals in the Puerto Rican area has been determined. White whales respond regularly to the playback of a long loud whistle, one of their many sounds. Detailed sounds and behavioral observations were made of the bottlenose whale a member of the beaked whale family.

The duration and fundamental of the boatwhistle call of toadfish differs between Narragansett and Chesapeake Bay individuals. Transfer experiments suggest that immediate changes in environment do not change the call. Fish from Chesapeake Bay for the first time called in large tanks. Tile spacing experiments are being summarized. A large number of playback tests delineating the characteristics of vocal facilitation will be published. Frequency, time and amplitude must all be within a certain range to evoke increased calling. Behavioral threshold response curves were obtained.

Trapping data for three years on the American eel allowed for a determination of the environmental correlates to downstream migration (fall period, dark of the moon, rain, etc). The increase in eye size especially in males started in mid to late summer as did gonad development. Activity cycles and directional activity in special tanks was obtained. Attempts were made to obtain adult eels in the Sargasso Sea. Live European and American eels were compared. Alewives apparently identify their home river by odor. Juvenile alewives pass downstream at night in small numbers during periods of normal, late summer weather, ie. water temperature approximately 20°C and little rain fall. With heavy rain and subsequent increased stream runoff, fish moved out in large numbers, with peaks of movement around noon and sunset.



### PLANS FOR FUTURE

A continuation of the studies mentioned in the abstract.  
Publication of results to date.

### CURRENT REPORTS AND PUBLICATIONS

- (a) James F. Fish (1968), "The effect of sound playback on the toadfish (Opsanus tau).". Abstract. Amer. Zool. 8(3).
- (b) J. F. Fish and H. E. Winn (1969), "Sounds of marine animals." In: Encyclopedia of Marine Resources. Reinhold, N.Y., Ed. F. E. Firth.
- (c) B. E. Thunberg (1970), "Olfaction in parent stream selection by the alewife, Alosa pseudoharengus. Animal Behavior. (in press)

#### BIODETERIORATION

These studies are supported in an effort to stem the costly failures resulting from biological interference with Naval vessels and other underwater structures. As Naval operations move to greater depths, knowledge of fouling and boring organisms which affect buoys, cables, various fixed structures and deep submersibles will have to be available. The investigation of these problems requires studies which probe into the physical and chemical aspects of the organism's environment, its behavior and its life history. Only when the organism, as a representative of its environment, is understood can appropriate control measures be taken in an efficient manner.

STUDIES ON MOLTING AND GROWTH IN LARVAL AND  
ADULT BARNACLES AND LARVAL DECAPODS

J. D. Costlow, Jr.  
Duke University Marine Laboratory  
Beaufort, North Carolina

ASSISTED BY G. Payen and J. Adams

WORK UNIT NO. NR 104-194

CONTRACT N0014-67-A-0251-0006

OBJECTIVES

(1) To determine the endocrine mechanisms which regulate molting, rate of development, metamorphosis, osmotic balance, and sexual differentiation in larvae of the Cirripedia (barnacles) and Brachyura (true crabs)

(2) To study the interaction of extracts of different endocrine systems on other systems within the same animals as well as the interaction of extracts of endocrine systems from different groups within the Crustacea and Insecta and their effect on molting, rate of larval development, growth, osmoregulation, and metamorphosis of larvae from other groups.

ABSTRACT

Through the use of a biolaser specific sites of endocrine activity in the eyestalks of decapod larvae and eyes of Limulus larvae have been irradiated to determine the way in which these glands develop, the effect of their destruction on the remaining endocrine mechanisms, and the way in which the entire hormonal complex is interrelated in control of rate of morphological development, ecdysis, metamorphosis, sexual differentiation, and osmoregulation. The studies on the effect of injection of molting hormone and juvenile hormone on frequency of molting and metamorphosis in larvae of the horseshoe crab Limulus and Rhithropanopeus harrisi, a brachyuran crab, have been continued. A number of synthetic hormones have been used, including  $\alpha$  ecdysone,  $\beta$  ecdysone, and  $\beta$  SEAL. Limulus larvae which are exposed to different concentrations while high concentrations frequently have lethal side effects. Preliminary experiments with the megalopa of Callinectes have indicated that the concentration of juvenile hormone and molting hormone which were employed have no effect on metamorphosis or frequency of molting.

## PLANS FOR FUTURE

Studies during the next six months will concentrate on the way in which insect hormones, both molting hormones and juvenile hormones, may affect the rate of molting and metamorphosis of a variety of crustacean larvae. Further experiments with the biolaser, are planned although certain technical difficulties (in vitro staining of the cells which are to be irradiated) must be resolved. Studies on the grafting of tissues from larvae and adults will be continued to determine the way in which sexual differentiation is regulated by the androgenic gland of Crustacea.

## CURRENT REPORTS AND PUBLICATIONS

(a) G. Payen, J. D. Costlow, Jr., and H. Charniaux-Cotton (1969), "Mise en evidence experimentale de l'indépendance de la réalisation du sexe chez le Crabe Rhithropanopeus harrisii (Gould) a l'égard du complexe neurosecreteur organe de Hanstrom-glande du sinus." C.R. Acad. Sc. Paris, 269, 1878-1881

(b) G. Payen (1970), "Etude ultrastructurale des glandes androgenes hypertrophiees a la suite de l'ablation des pedoncles oculaires au premier stade larvaire chez le Crabe Rhithropanopeus harrisii (Gould)." C. R. Acad. Sc. Paris, 270, 1499-1502

(c) T. C. Jegla and J. D. Costlow, Jr. (1970), "Induction of molting in horseshoe crab larvae by polyhydroxy steroids." Gen. and Comp. Endocrinology, 14, 295-302

BIOLOGY AND ECOLOGY OF ENCRUSTING BRYOZOANS  
IN MONTEREY HARBOR

E. C. Haderlie  
Naval Postgraduate School  
Monterey, California

ASSISTED BY

WORK UNIT NO. NR 104-102

CONTRACT

OBJECTIVES

(a) To study the basic biology and ecology of three common encrusting bryozoans found in the harbor at Monterey, California, (b) to determine the period of reproduction and settlement of the larvae, (c) to measure rates of growth, (d) to determine food habits, (e) to investigate the influence of the bryozoans on the settlement of other fouling organisms, and (f) to study a common predator feeding on the bryozoans.

ABSTRACT

The encrusting bryozoans Celleporaria brunnea, Cryptosula pallasi, and Tubulipora tuba are the dominant encrusting bryozoans in the Monterey Harbor. By using fouling panels as collecting surfaces the settlement periods of these bryozoans have been determined. Celleporaria brunnea settled throughout the year, but the other two have more restricted periods of settlement. The rate of growth at different depths and at different seasons has been determined. So far food habits have not been elucidated, for digestion in the gut is so rapid that it has proven impossible from dissections to determine what is being ingested. Extensive colonies of these bryozoans, especially Celleporaria, seem to definitely prevent the settlement of barnacle and serpulid larvae, and inhibit the activities of wood borers such as Limnoria. No active predators were found on any of the bryozoan colonies except Celleporaria and in this case the flatworm Thysanozoon californicum was commonly found feeding on the living polyps (polypides). The flatworm was never encountered except on the colonies of these bryozoans where it left large white and dead patches before it moved on to another area.

### **PLANS FOR FUTURE**

(a) To continue the study of the basic biology and ecology of these encrusting bryozoans over an extended period of time, (b) to try to develop means of keeping panels with reproductively mature bryozoans in aquaria so that a laboratory investigation of the larvae and larval settlement could be made, and (c) additional attempts to determine the food habits of these organisms.

### **CURRENT REPORTS AND PUBLICATIONS**

The following current publication was partially supported by this contract.

E. C. Haderlie (1969), "Marine fouling and boring organisms in Monterey Harbor--II. Second year of investigation." The Veliger 12(2): 182-192.

## BIOLOGICAL STUDIES ON MARINE BORING AND FOULING MOLLUSKS

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ASSISTED BY J. L. Oulliney, G. Burger, and P. Boyle

WORK UNIT NO. NR 1866(45)

CONTRACT N00014-67-A-0298-  
0027

### OBJECTIVES

(a) To study the life histories of shallow water marine boring and fouling mollusks with special emphasis on identification of larvae, length of larval life and factors controlling dispersal, (b) to understand factors affecting settlement and metamorphosis of the larvae, (c) to study the ecology, distribution and systematics of deep water boring mollusks (Pholadidae, subfamily Xylophaginae), (d) to establish the means by which teredinids utilize wood.

### ABSTRACT

Our continuing program of photographic cataloging of larvae of boring and fouling mollusks has been enhanced by the first scanning electron micrographs of shipworm larvae. This new technique promises to be a powerful tool for identification of bivalve mollusk larvae in general. We have begun studies of larval behavior with 16 mm. motion pictures, taken through the microscope, including a time lapse study of metamorphosis.

Improved techniques have enabled us to rear larvae throughout the year in mass cultures, and we are now maintaining nearly two dozen species of boring and fouling mollusks in the laboratory. We have been successful in inducing gonad maturation and spawning of a number of species in the laboratory.

We have continued to cooperate with Ralph Mitchell, Prof. of Applied Biology, Environmental Engineering, Harvard University, in a research program on the relationship of fouling to primary films on surfaces in sea water. We are regularly supplying large numbers of larvae of oysters and other fouling species to Lily Young, a graduate student under Dr. Mitchell, who is investigating interactions of bacteria with larvae at the time of settlement.

Dr. H. W. Riser of Northeastern University has continued his studies of potential parasites and enemies of boring and fouling mollusks and will present findings at the 1970 AAAS Annual Meeting.

An extensive monograph has been completed on the Xylo-

phagainae which includes descriptions of a number of new species and notes on ecology, distribution and life history. This will be submitted for publication in the near future.

As in the past we have continued to cooperate with the Naval Oceanographic Office and the Naval Civil Engineering Laboratory in identifying boring and fouling mollusks sent to us from around the world.

#### PLANS FOR FUTURE

(a) Obtain living teredinid wood-borers from Hawaii, the Mediterranean Sea, Australia, and New Guinea for studies of larval biology and cataloging of larvae. (b) Begin life history studies of living Xylophaga, including deep sea species. (c) Organize a conference on biological problems of boring and fouling mollusks in order to exchange ideas and coordinate research. (d) Plan and propose field research on biodeterioration to be carried out from the Tektite undersea habitat. (e) Plan and propose a program using a research submersible for observational, photographic, and mapping studies of deep water boring and fouling organisms (in cooperation with Robert Ballard, Woods Hole Oceanographic Institution).

#### CURRENT REPORT AND PUBLICATIONS

(a) R. D. Turner (1969) "The Pholadacea." in Treatise on Invertebrate Paleontology, R. D. Moore. ed. 93 pp., 53 pls.

(b) R. D. Turner and A. C. Johnson (1969) Some problems and techniques in rearing bivalve larvae. The American Malacological Union: Annual Repts. for 1969. pp. 9-13.

(c) F. A. Rosenberg and H. Breiter (1969) The role of cellulolytic bacteria in the digestive processes of the shipworm: I. Isolation of some cellulolytic microorganisms from the digestive system of teredine borers and associated waters. Material und Organismen 4 (1969) H. 2, 147-159.

(d) J. L. Oulliney (1969) Larval biology and recruitment of the shipworms Teredo navalis and Bankia gouldi in the Newport Estuary, North Carolina. Ph.D. Thesis, Duke University. 174 pp.

(e) J. L. Oulliney (in press) Laboratory rearing of the larvae of the mahogany date mussel, Lithophaga bisulcata. Bull. Mar. Sci.

(f) R. D. Turner (in press) Identification of marine wood-boring mollusks. O.E.C.D. Handbook on Biodeterioration of Wood. 61 pp. (keys fully illustrated).

(g) R. D. Turner and A. C. Johnson (in press) Biology of marine wood-boring mollusks. O.E.C.D. Handbook on Biodeterioration of Wood. 65 pp., 14 pls.



#### NOXIOUS MARINE ANIMALS

Studies on noxious marine animals are supported because of the important effects these creatures have on Naval personnel under survival conditions or during swimmer-diver operations. Ecological studies of known toxic species and the continuing search for unreported toxic relatives is required. Shell fish toxins, fish toxins, such as ciguatera, and echinoderm toxins are being studied with regard to their occurrence geographically. The behavioral aspects of sharks constitutes part of a broader program on these noxious animals.

## PHYSICAL AND CHEMICAL FACTORS INFLUENCING SHARK BEHAVIOR

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WORK UNIT NO. NR 104-025

CONTRACT Project Order P0-0-0017

### OBJECTIVES

(a) To broaden the scientific base necessary for development of new and more effective means for controlling predaceous shark activity, (b) to clarify further the factors associated with known instances of shark attack on man, (c) to develop reliable assay procedures for determining shark repellent activity, and (d) to identify as yet unrecognized aspects of shark biology which might provide a basis for new approaches to anti-shark measures.

### ABSTRACT

Earlier phases of this project included (a) studies on factors associated with shark attack on mammals in which behavioral patterns of sharks were observed in the presence of large laboratory-bred rats in varying degrees of distress, (b) study of behavioral manifestations of physiological responses as functions of time of exposure of sharks to waterborne drugs, (c) development on the basis of shark catch-records of a reference size (3 meters long, weighing 200 kilograms) of shark for use as a design parameter in the development of certain anti-shark devices, and (d) development and use of procedures for assimilating and codifying information held in the International Shark Attack File on approximately 1500 cases of shark attacks on humans.

Data held on code sheets prepared in a year-long review of the Shark Attack File were transferred to IBM cards and then to magnetic tape at the Data Processing Department, Naval Aerospace Medical Center, Pensacola. After checks for illegal codes, computer runs were conducted to determine totals and percentages for each response code under each of the approximately 90 questions asked of individual shark attack cases. As expected, these summations and percentages in general support the findings of earlier investigators, since very little interrelating of available information was involved in these preliminary analyses.

The practicability of incapacitating an approaching shark by waterborne drugs was analyzed as a system. A mathematical model was developed describing exposure to waterborne drug experienced by a shark as it approaches a man in the water at the center of an idealized drug field. By relating this level of exposure (integral of time and drug concentration) to that found in earlier tank studies for effective immobilization of a shark, an estimate was made of the quantity of toxic material required to establish the drug field. Results of this analysis indicate that it is highly impractical, because of the very large quantity of drug required,

to hope to produce an effective level of incapacitation in a shark by exposure to waterborne drugs as the shark approaches a man in the water.

Studies have continued on probing the sensitive nature of the hydrostatic balance maintained by large sharks and the possibility of exploiting this sensitivity to the shark's disfavor. In species characterized by very large adult sizes, storage of oil in the liver occurs at such a rate that optimum hydrostatic relationships are maintained between growing sharks and their environment.

In collaboration with Dr. Scott Johnson of the Naval Undersea Research and Development Center, San Diego, tests were conducted on several design modifications of an electric anti-shark weapon for use primarily by divers. The weapon is a self-contained electric dart deliverable by a conventional spear-gun or hand-held lance and would be capable of instantly immobilizing a large shark by a flow of current from the dart's imbedded tip thru a multiplicity of pathways in the shark's body to the surrounding sea water and hence to the external electrode of the dart.

#### PLANS FOR FUTURE

(a) To continue to study the kinetics of onset of responses elicited from sharks by waterborne drugs with a view towards correlation of onset times with blood/tissue concentrations and calculation of additional kinetic and thermodynamic factors, (b) to examine effects of varying levels of oil in the shark's liver on onset times for responses to waterborne drugs, (c) to plan and conduct in collaboration with several other scientists a computer analysis of shark attack data, (d) to continue to probe the delicate hydrostatic balance maintained by large sharks with the idea of possibly exploiting the sensitivity of this balance for anti-shark purposes, and (e) to continue the development of the electric dart.

#### CURRENT REPORTS AND PUBLICATIONS

- (a) Baldrige, H. D. (1968), "A proposed reference shark." *Military Medicine*, 133, 654-662.
- (b) Baldrige, H. D. and J. Williams (1969), "Shark attack: feeding or fighting?" *Military Medicine*, 134, 130-133.
- (c) Baldrige, H. D. and S. Johnson (1969), "Antishark measures." *Naval Research Reviews*. April, 15-22.
- (d) Baldrige, H. D. (1969), "Analytic indication of the impracticability of incapacitating an attacking shark by exposure to waterborne drugs." *Military Medicine*, 134, 1450-1453.
- (e) Baldrige, H. D. (1969), "Kinetics of onset of responses by sharks to waterborne drugs." *Bull. Marine Sci.* 19, No. 4, 880-896.
- (f) Baldrige, H. D. (1969), "International shark attack file data assimilation program-final report." Submitted to the Smithsonian Institution via the Mote Marine Laboratory, Sarasota, Florida, 15 March 1969.
- (g) Baldrige, H. D. (1970), "Sinking factors and average densities of Florida sharks as functions of liver buoyancy." *Copeia*, accepted for publication.

## RESEARCH ON TROPICAL MARINE ANIMALS

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WORK UNIT NO. NR

CONTRACT N00014--67--C--0127

### OBJECTIVES

I. To investigate toxins of marine organisms associated with coral reefs that may, directly or indirectly, enter the diet of man; these investigations will seek the chemical and pharmacological identification of the toxin, and endeavor to trace it through the food web of the coral reefs.

II. To survey for dangerous concentrations of the Crown-of-Thorns starfish, Acanthaster planci, and to initiate studies on its biology and ecological effects; funds were granted only to assist in the work of the summer and fall of 1969.

### ABSTRACT

I. In the past year the work on marine toxins has been confined to the toxins causing ciguatera. In chemistry, the whole purification procedure has been reviewed, resulting in a more efficient procedure and a more highly purified product; crystalline mercury derivatives have been prepared which should expedite the final determination of chemical structure. In pharmacology, we have discovered that ciguatoxin interferes with the Na<sup>+</sup> permeability of cell membranes; this accounts for the observed motor and neurological symptoms in the disease. In biology we have discovered in cooperation with our Japanese colleagues, that both the flesh and the gut contents of the Tahitian detrital feeding acanthurid, Ctenochaetus striatus contain a toxin closely similar to or identical with ciguatoxin from reef carnivores, in addition to other aqueous and lipoidal toxins. In microbiology we have isolated a number of strains of yeasts from C. striatus that produce aqueous or lipoidal toxins.

II. We have surveyed selected islands of the Marshall and Hawaiian chains, as well as Johnston Island for Acanthaster. In September, a major concentration was found in about 60 feet of water on the south central reef off Molokai in Hawaii. Since that time the concentration was studied and followed in spite of the exhaustion of the research funds in November 1969; the last study was made in early April. The concentration estimated at 20,000 individuals, had destroyed only about 5 - 15% of the growing coral on the reef, selectively feeding on Montipora in preference to the Porites that makes up the bulk of the reef; they showed signs of only sporadic spawning until April, when it is believed (but not observed in the field) that they had a spawning peak. Morphometric and population data was taken during all surveys.

## PLANS FOR FUTURE

I. On the disease, ciguatera, to continue the studies on the chemical structure of the toxin, and to use the pharmacological tests presently developed to seek its biological origin and mode of transmission of the toxin; in time, to investigate other toxins discovered. This work will be contingent upon major funding by other agencies.

II. The work on Acanthaster will be supported this coming year by a special grant from National Science Foundation - Sea Grant and will be under another principal investigator.

## CURRENT REPORT AND PUBLICATIONS

(a) M. D. Rayner, M. Baslow and T. I. Kosaki (1969), "Marine toxins from the Pacific, VI: Ciguatoxin: not an in vivo anticholinesterase." J. Fish Res. Bd. Can. 26(8): 2208-2210

(b) J. A. Setliff, M. D. Rayner and S. K. Hong (1969), "Effects of ciguatoxin on Na transport across the frog skin." The Physiologist 12(3): 353.

(c) M. D. Rayner (1969) "Marine Toxins from the Pacific, VII: Recent advances in the pharmacology of ciguatoxin." Proc. Food/Drug from the Sea, Conference.

(d) L. L. Boyarsky, M. D. Rayner (in press), "The effect of ciguatoxin on Aplysia neurons." Proc. Soc. Exp. Biol. Med.

(e) T. Yasumoto, P. J. Scheuer. "Marine Toxins of the Pacific - VIII. Ciguatoxin from Moray Eels Livers." Toxicon, 7(4): 251-344.

## RESPONSE PATTERNS OF PORPOISES AND DANGEROUS SHARKS

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WORK UNIT NO. NR 104-471

CONTRACT N00014-69-C-0340

### OBJECTIVES

(a) To observe and analyze the behavioral responses of several species of dangerous sharks, 6'-12' in length, to the presence of adult porpoises (Tursiops truncatus) and vice versa; to examine the effect, if any, on sharks of the sonic signals porpoises emit; (b) to train 2 or more porpoises to aggressively contact sharks; (c) to train these same porpoises to work reliably in the open sea environment; and (d) to utilize the porpoises thus trained to detect and ward off sharks attracted to a given area in the open sea.

### ABSTRACT

Preliminary experiments with sharks and porpoises have been carried out at the Lerner Marine Laboratory in collaboration with Robert F. Mathewson and Capt. H. D. Baldrige (USN). In these experiments adult sharks of three species (Negaprion brevirostris, Carcharhinus obscurus, and Galeocerdo cuvieri) were introduced into a pen 80' x 40' x 8' containing one or two adult, recently captured, and untrained porpoises (Tursiops truncatus). The porpoises occupied the entire central portion of the pen and effectively kept the sharks from invading their "territory." The porpoises appeared to utilize sonic signals in locating a shark and moving toward it. Once the porpoises closed in on a shark, the sonic signals often ceased. It appeared that the presence of the porpoise at close range was sufficient to cause a shark to change course.

At the Mote Marine Laboratory, we are now studying the behavioral responses of five species of sharks, 6' to 12' in length, to the presence of adult porpoises (Tursiops truncatus) and vice versa, and are observing the possible effect of porpoise sonic signals on sharks. Sharks used in this study include: lemon (Negaprion brevirostris), brown (Carcharhinus milberti), dusky (Carcharhinus obscurus), bull (Carcharhinus leucas), and tiger (Galeocerdo cuvieri). The behavior of the sharks and porpoises is recorded on 16mm motion picture film and the sonic signals of the porpoises are taped with an Ampex 601 recorder.

## PLANS FOR FUTURE

Once our observations and analyses for the above part of the program are complete, we will concentrate on training porpoises (Tursiops truncatus) to detect and aggressively contact sharks and to work reliably in the open sea. We plan experiments in which the porpoises thus trained will be employed to ward off sharks that have been attracted to a given area in the open sea.

## CURRENT REPORTS AND PUBLICATIONS

- (a) Gilbert, P. W. 1968. The shark: barbarian and benefactor. *BioScience* 18: 946-950.
- (b) Gilbert, P. W. 1968. Report on the use of the NUWC shark screen as a deterrent to sharks. Cornell University for the Research and Engineering Department, San Diego, Calif., Naval Undersea Warfare Center. 30 p. (NUWC TP 52)
- (c) Wang, J. C. S., P. W. Gilbert. 1968. Changes in the eye of nurse and lemon sharks during light and dark adaptation. *Am. Zool.* 8: 366.
- (d) Gilbert, P. W. 1969. Sharks: behavior and attack patterns. In F. E. Firth, (ed.), *The encyclopedia of marine resources*. Litton Educational Publishing Inc., New York. Pp. 633-635.

## A STUDY ON THE VENOMOUS FISHES AND SEA SNAKES OF SOUTHEAST ASIA

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WORK UNIT NO. NR

CONTRACT N00014-67-C-0379

### OBJECTIVES

To determine the incidence, species identification, morphology of the venom apparatus, and aggressive behavior of the venomous fishes and sea snakes of Southeast Asia as they relate to naval operations. With the beginning of the current fiscal year it was recommended that our research operations be extended to include other parts of the world as well in view of the fact that the U.S. Navy must have a global operational capability.

### ABSTRACT

Laboratory work this past year has focused primarily on three groups of organisms, viz: venomous rabbitfishes, scorpionfishes, and sea snakes. However, several other species of venomous fishes (Scomberomorus sanctipetri), poisonous crabs, and a stinging hydroid (Rhizophysa eysenhardti). Our work on rabbitfishes has now been completed. One of the more significant discoveries this past year has been the finding of highly developed venom organs in a wide range of species of deep water scorpionfishes of the genus Sebastes along the coast of southern California. We are now doing an intensive investigation of this entire group. Moreover, we have recently been offered a large collection of venomous scorpionfish through Dr. Wm. N. Eschmeyer, California Academy of Sciences, Golden Gate Park, San Francisco, California. This collection is world-wide and contains a broad range of species. All of these venomous fishes are of direct operational significance to the Navy's man-in-the-sea program.

During the past fiscal year the following field trips and collections were made: Palau, Western Caroline Islands, by Dr. Bruce W. Halstead and Dr. Everette J. Mallory, during 2-14 May 1969; Rangiroa, Tuamotu Islands, a 20-man expedition headed by Dr. Bruce W. Halstead in collaboration with the French Polynesian Government and the French Military, during 28 June - 4 August 1969; USSR (Vladivostok, Irkutsk, Novosibirsk, Tashkent), Afghanistan, India, Nepal, Cambodia, Hong Kong, Japan, and the Philippine Islands, by Dr. Bruce W. Halstead, during 7 October - 11 November 1969; Indonesia, Japan, Israel, and France, by Dr. and Mrs. Bruce W. Halstead, and Mr. and Mrs. James Danielson, during 14 February - 7 March 1970. The field work conducted during this past year has provided valuable specimens of venomous fishes



of venomous fishes (scorpionfishes, rabbitfishes, etc.) and a violently venomous sea anemone (*Triactis productis*). The Rangiroa Expedition made possible the production of a 50-minute 16 mm. sound/color underwater movie on biomedical oceanography. This film was produced in collaboration with the Brooks Institute of Photography at Santa Barbara, California.

#### PLANS FOR FUTURE

Work will be intensified on the morphology of the venom organs of sea snakes. Work will also be expanded on the venom organs of the scorpionfishes of the world. This work is of particular importance to the U.S. Navy since these fishes range from intertidal zones to deep water and are of immediate naval medical importance. We would like to expand our program to add a full-time marine ecologist to the project in order to extend our work on the aggressive behavior of these fishes. Also, we would like to begin work in the near future on the ultrastructure of these venom glands with the use of electron microscopy.

#### CURRENT REPORT AND PUBLICATIONS

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(b) T.S. Cooke and B.W. Halstead (1970), "Report of stings by the coelenterate Rhizophysa eysenhardti Gegenbaur in California waters." Clin. Toxicol. (In Press)

(c) B.W. Halstead (1969), "Recommendations to the President's Commission on marine science, engineering, and resources for a national program in marine biomedicine." Proc. 2nd Symp. Food and Drugs From the Sea.

(d) B.W. Halstead (1970), "Drugs from the ocean depths." This Is Japan. (In Press)

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(f) B.W. Halstead (1970), "Marine pharmaceuticals and economic development." Mar. Tech. Soc. J. (In Press)

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(h) B.W. Halstead, P.C. Engen, and D.D. Danielson (1970), "Morphology of the venom organs of the rabbitfishes (family Teuthidae)." Proc. 2nd Internat. Symp. Animal and Plant Toxins (In Press)

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W.F. Rathjen and B.W. Halstead (1969), "Report on two fatalities due to stingrays." Toxicon 6, 301-302.

EXPERIMENTAL STUDY OF AMINO ACIDS AND AMINES AS  
CUES FOR FEEDING AND AGGREGATIONS IN SHARKS.

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ASSISTED BY Mr. Allan VanArsdale and Mrs. V. Hodgson.

WORK UNIT NO. NR

CONTRACT NONR 552(07).

OBJECTIVES

To test in a semi-natural situation the behavioral responses of sharks to compounds found extremely effective in EEG studies. To measure the responses which appear to demonstrate either a strong attractant or repellent effect.

ABSTRACT

It is necessary in this interim report to point out that very early in the initial tests it became apparent that one of the assumptions previously made about shark behavior was probably incorrect. Responses to chemical stimulants by the lemon and tiger sharks, unlike expected behavior patterns, were demonstrated by the animals following the stronger water currents and swimming against them rather than homing in on the source. Nurse sharks however showed a consistent ability to home in on the source.

Ginglymostoma

Nurse sharks usually lie on the bottom at whatever part of the enclosure is shaded from the sun; they head upstream, but spend most of the day immobile. They appear to be crepuscular, swimming especially actively at twilight; unfortunately, this is not an easy period for making precise observations and all our experiments in this series were performed in daylight. Nurse sharks react to chemical stimulation by swimming directly toward the source. In 8 experiments involving 6 individual sharks in each experiment, the nurse sharks consistently localized the source of chemical stimulants before the lemon shark. Observations suggest that they can indeed, discriminate differences in concentrations impinging upon sense organs on the two sides of the head, and that this ability can be used to "home-in" on a source chemical stimuli at least 40 ft. away.

#### Negaprior

Responses to glycine - TMA mixture.

12 Experiments which were analyzed in detail indicate that the sharks do not "home-in" on the source of chemicals but that the chemical stimulation triggers a rheotaxis, such that the shark heads "upstream". This may be construed as evidence for a repellent. This however was tested for and if the source was moved into the area of strongest current the animals would still seek this area to swim against.

This result was totally unexpected and caused us to spend the greater part of our testing period checking and rechecking it. It is obviously terribly important for any behavioral analysis, since it makes unnecessary any mechanisms for comparing concentrations of chemicals passing through two nasal sac, at least until the animal is very close to a source of chemical stimulus. It has forced us to rethink parts of our experimental design, paying much more attention to the roll of water movements, especially sustained current flows.

#### PLANS FOR FUTURE

Plans for future work will be within the general frame work of our original proposal, but with some modification to take advantage of the new insights from the experiments noted above. Clearly, we are now ready to move the animals and observations to a new, larger, more isolated environment. We shall have to make much more careful measurements of water currents than we had anticipated would be necessary. An enclosure measuring at least 100ft. in diameter, and further removed from noise of boats and other confined animals, will be constructed. We are also considering making a few tests in a very quiet area far removed from the boat channel, such as one of the "lakes" in the mangrove areas of East Bimini; this would supplement, but not replace, the other tests in a large semi-natural environment enclosure. It would be desirable also to test our results on the rheotaxis response and the response to amines and amino acids in open-sea conditions.

## RESEARCH ON THE BEHAVIOR AND SENSORY PHYSIOLOGY OF SHARKS

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WORK UNIT NO. NR 104-587

CONTRACT N00014-67-A-0201-0008

### OBJECTIVES

(a) Clarifying, experimentally, the functional significance of biological sounds to small, free-ranging lemon sharks, (b) determining the relative effectiveness of various frequency bands and pulse rates for attracting sharks which frequent the deep reef and "blue waters", (c) characterizing the various types of motor patterns exhibited by certain species of inshore sharks under conditions of isolation and group interaction.

### ABSTRACT

Turbulent sounds of locomotion as well as sounds accompanying feeding activity have been recorded and analyzed from various fishes and invertebrates frequenting a shallow water field station in Biscayne Bay, Florida. This catalog emphasizes those sources which are either prey of the lemon shark, Negaprion brevirostris, or species that are extremely prevalent at the test site. Source levels are known for all the included sounds, this being of paramount importance for purposes of sonic playback. Sound transmission tests, including numerous types of acoustic signals, have been carried out at the field station to establish attenuation rates with distance from specific sources. Rates for continuous, or long-term signals ( $> 10$  sec), were found to be significantly greater than those obtained for brief pulses (20 ms - 400 ms) and therefore, attenuation rates are being determined for the various biological sounds which are used in playback tests. Based on present evidence, apparently many of the low level, feeding and motor sounds produced by various invertebrate prey are heard only at extremely close range by lemons and such will assuredly be well within their visual range under all, but the most turbid, conditions. The uncommonly high winds and seas that have frequented southeastern Florida during this last fall and winter have simply precluded sufficient field testing to allow further generalizations at this time.

Four cruises were made on the R/V Observer during this late fall and winter to Triumph Reef (southeast of Miami), Looe Key (southeast of Marathon, Florida Keys), and Sand Key (south of Key West) for the specific purpose of determining preferential attraction by sharks to various instrumental signals, incorporating different octave bands (25-50, 75-150, 250-500, 500-1000 Hz) and also differing pulse rates (1/sec, 5/sec, 10/sec, irregular). The R/V Observer, a 40' floating laboratory, was outfitted with acoustic and supplementary instrumentation including UTV. High winds, high seas, and extreme turbidity, characterizing our waters for the past several months, have, again, rather consistently frustrated our efforts to gather needed data from the field. With only about 60 tests completed thus far, caution must be given any generalization; but it appears that sharks are not being attracted by the above "band" signals during playback periods that involve pulse rates of either 5/ or 10/sec. On the other hand, rapid but irregular pulse rates (including rates varying from 1/ to 10/sec) covering the same "band" signals appear clearly attractive to

sharks (e.g., bulls, Carcharhinus leucas), especially in the range of 250-500 and 500-1000 Hz. These findings, though few in number, fit well with our previous results dealing with other sharks at Bimini. Unfortunately, we have attracted only one or two sharks at a time during these field tests and so our desires to test human sounds in the presence of such animals or to playback certain sounds that may even result in short-term withdrawal have, as yet, remained unrealized.

Interest in characterizing the various types of motor patterns exhibited by certain species of inshore sharks has arisen from the ever-increasing need for greater accuracy in determining responsiveness to given stimulus conditions. Movements toward, and movements away from various stimulus situations, though adequate as behavioral measurements in many instances, might well follow other more subtle response patterns, which, in turn, would allow us to make earlier predictions of subsequent behavior. Blacknose, Carcharhinus acronotus, and bonnetheads, Sphyrna tiburo, have been the species of interest in this connection since neither require the large maintenance facilities demanded by their near relatives. The former species is being kept in a large pool in the Keys, while a group of ten bonnets is presently being intensively observed in a large tide-pool enclosure at the Miami Seaquarium. The tide-pool habitat is supplying a wealth of information. Various action patterns have been observed; some appearing during group interactions while others are carried out individually. An incidental finding, arising from quantitative observations, has been that a consistent size-dependent, social hierarchy is present in this group of bonnets.

#### PLANS FOR FUTURE

(a) To complete the sound playback tests at our shallow water test site in Biscayne Bay, (b) to continue our field tests off Triumph, Looe, and Sand Keys, regarding preferential attraction of sharks to differing instrumental, acoustic signals (variables being frequency and pulse rates), and to test also the effects of various human sounds and other signals in the near vicinity of sharks, (c) to continue intensive observations of selected species of sharks for purposes of gaining insight into the probable causation of specific response patterns shown by animals under semi-natural conditions, (d) Dr. Samuel Gruber will carry on his research interests in vision physiology of sharks separately from this contract, but close cooperation is anticipated.

#### CURRENT REPORTS AND PUBLICATIONS

- (a) A. Banner (1970), "Sound propagation in a shallow bay." J. Acoust. Soc. Amer. (In Press - 5 p., 5 figs.)
- (b) S. H. Gruber (1969), "Physiology of vision in the lemon shark, Negaprion brevirostris (Poey): a behavioral analysis." Doctoral Diss., U. of Miami, 104 p. (Diss. Abstracts, 31(4))
- (c) A. A. Myrberg, Jr. (1969), "Attraction of free-ranging sharks by acoustic signals." Gulf and Carib. Fisheries Inst., Proc., p. 135
- (d) A. A. Myrberg, Jr. (1970), "Behavior and sensory physiology of sharks." Contract No. Nonr 4008(10) - 1964-1969. Final Report, ONR (Code 484), Dept. of the Navy, 8 p.
- (e) A. A. Myrberg, Jr. (1970), "Using sound to control the behavior of free-ranging marine animals." In: Winn and Olla (Eds.) Behavior of Marine Animals - Recent Advances. (In Press - 27 p., 20 figs.)
- (f) A. A. Myrberg, Jr., A. Banner and J. D. Richard (1969), "Bio-acoustic studies on sharks." Tech. Rept. ONR (Code 484), Dept. of the Navy, 16 p.

# THE EXPERIMENTAL ANALYSIS OF HEARING AND ACOUSTIC ORIENTATION IN SHARKS

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ASSISTED BY R. H. Johnson, E. Standora

WORK UNIT NO. NR 104-062

CONTRACT N00014-68-C-0318

## OBJECTIVES

(a) To determine the capabilities and mechanisms of hearing and acoustic orientation in sharks under conditions from the near to the far fields, (b) to determine the role of the acoustic sense, and its relation to vision and olfaction, in natural shark behavior, and (c) to develop and utilize bio-telemetry techniques for remote prolonged study of the behavior of sharks at sea.

## ABSTRACT

The auditory capacities of sharks appear to differ from those of the more thoroughly studied bony fishes, especially in regard to directional hearing in the acoustic far field. While true directional hearing is well developed in certain sharks (possibly because of their lack of a gas bladder), it has yet to be demonstrated in teleosts. To further elucidate this matter, mechanisms of shark hearing are being investigated by several conditioning methods in the underwater "laboratory" at Catalina Island where acoustic conditions can be varied from near to far field.

During July 1969, acoustic playback studies were conducted at Rangiroa Atoll, French Polynesia, while on an expedition with B. Halstead of the World Life Research Institute, Colton, California. Responses to both artificially produced and naturally recorded low-frequency, pulsed sounds were observed in the blacktip reef shark, Carcharhinus melanopterus; the gray reef shark, C. menisorrh; and the reef whitetip, Triaenodon obesus. Responses were observed to the following sounds: 50-200Hz, hand pulsed-trained; 25-50Hz, electronically pulsed (15/sec.)-hand trained; 50-100Hz, elec. pulsed-hand trained; 50-100Hz, elec. pulsed-untrained; recorded speared-fish sound; and recorded fish stampede sound. Although there were insufficient data for valid comparison, the general impression was that the natural sounds were somewhat more attractive. For whitetip sharks, habituation to both natural and artificial sounds was observed when several series of sound and control periods were presented at fixed sites.

The speared and stampeded fish sounds were recorded from a group of bonefish, Albula sp., in a fish trap (pen) in the Rangiroa lagoon. Preliminary analysis indicates peak acoustic pressure at 150Hz (speared) and at 90Hz (stampeded). The primary pulse rate for the speared fish sound was about 5-10/sec., while the stampede sound was more irregularly pulsed at a somewhat higher rate. Additional hydrodynamic fish sounds (speared fish, hooked fish) were recorded in the Gulf of California while on a cruise

with W. C. Cummings of the Naval Undersea R and D Center, San Diego, and are presently being analysed.

Experiments on the acoustic behavior of blue sharks, Prionace glauca, are being continued in the open ocean off Long Beach. A new observation system is in operation utilizing scanning sonar and underwater TV to supplement direct visual surveillance from the surface. In addition to acoustic attraction, the possibility of aversive responses to certain sounds is being investigated, e.g., sharks cruising at the surface appear able to avoid an approaching human swimmer at distances beyond the limit of visibility - a probable acoustic response.

Considerable effort has been devoted towards the development of a multi-channel, ultrasonic, telemetry package for use in monitoring simultaneously several aspects of the behavior of unrestrained sharks at sea. New circuitry has been designed which simplifies data retrieval and reduces chances of error (compared to our earlier circuits). The unit transmits brief pulses of 40KHz, at a rate dependent on the resistance value of the sensors. Four channels of information are telemetered, all as pulse rate, by commutating successively between channels at the rate of one interpulse interval per channel. Present sensors measure depth, swimming speed, and compass heading (or, alternately, temperature and light), with the 4th channel used for a calibrate reference. Expected range of the unit is one mile, and its life several days or more - depending on battery size.

The units will be applied to sharks underwater with dart or clip applicators. Two tuneable receivers are used; a primary one for boat use, and another for underwater use by divers. Data from the receiver will be recorded on a strip-chart oscillograph for direct interpretation.

#### PLANS FOR FUTURE

(a) To continue tests of auditory capacities of sharks under the free-field acoustics of the underwater "laboratory" at Catalina Island, (b) to continue field-playback experiments including tests to determine relative values of acoustic, olfactory, and visual stimuli, (c) to record and analyze natural sounds believed of significance to sharks, and (d) to conduct a pilot biotelemetry study of diel rhythms in sharks in regard to several measurable behavioral variables.

#### CURRENT REPORTS AND PUBLICATIONS

(a) D. R. Nelson, R. H. Johnson, and L. G. Waldrop (1969), "Responses in Bahamian sharks and groupers to low-frequency, pulsed sounds." Bull. S. Cal. Acad. Sci., 68(3): 131-137.

(b) D. R. Nelson and R. H. Johnson (in press), "Diel activity rhythms in the nocturnal, bottom-dwelling sharks Heterodontus francisci, and Cephaloscyllium ventriosum." Copeia.

(c) D. R. Nelson (1969), "Meeting the shark underwater." Underwater Naturalist 6(2): 13-26.

(d) D. R. Nelson (1970), "Acoustic studies on sharks - Rangiroa Atoll, July 1969." ONR Tech. Rep. (2).



## STUDIES ON THE SCULPIN SCORPAENA GUTTATA

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WORK UNIT NO. NR 104-793

CONTRACT N00014-67-C-0390

### OBJECTIVES

(a) To describe the anatomy of the venom apparatus and the mechanism of venom production; (b) to isolate, stabilize and characterize certain components of the venom; (c) to determine the physiopathology following envenomation; and (d) to develop measures for treating stings by these fish.

### ABSTRACT

The venom is produced in large epithelial cells in the antero-lateral grooves of the dorsal, pelvic and anal spines. It is introduced into the spine puncture wound by the mechanical tearing of the integumentary sheath surrounding the fin spine. Although the venom contains many components, the lethal properties are associated with certain heat-labile protein fractions.

Two methods of extraction of venom from spines have been developed: (a) aspiration of the spine grooves with a micropipette, followed by centrifugation and lyophilization of the venom-containing tissues; (b) removal of the interspinous fin tissues and the stripping away of the integumentary sheath. The entire spine is then placed in distilled water or a buffer solution. After removal of the spine the extracting medium is lyophilized. Upon reconstitution, the cellular debris is removed by centrifugation. All operations are conducted at 5°C.

These methods produced venom extracts having a yield of 0.6 mg venom protein per spine; the intravenous LD<sub>50</sub> in mice was 1.06 mg/kg body weight. Lyophilized extracts were lethal upon reconstitution with water or buffer solutions after 9 months of cold storage.

Exposure of the venom extracts to oxidizing agents caused an immediate loss in lethality. The decline in toxicity in water or buffer solutions could be inhibited by the addition of reducing agents, including Cleland's reagent, a specific SH group protective reagent. Extracts could be kept at 5°C in buffer solutions of pH 5.7 to 8.0 for several days with but a minimal loss in activity, if Cleland's reagent was added to the medium.

Following gel filtration chromatography with Sephadex G50 and G200, lethal activity was found to be associated with the high molecular weight protein peaks. Ion exchange chromatography, cellulose acetate electrophoresis and polyacrylamide gel electrophoresis of the venom extracts indicated that the lethal fraction(s) possessed a moderate negative charge in the pH range of 5.7 to 8.6.

Although the venom possesses a potent pain producing factor the most serious effects of poisoning are directed against the cardiovascular, and perhaps, the respiratory systems. An intravenous dose of 1.0 mg/kg in anesthetized mammals caused an almost immediate fall in systemic arterial blood pressure followed within 30 seconds by a rise in central venous pressure. Respiratory standstill occurred within the first minute post-injection. Animals which survive this dose reinstitute spontaneous respiration within 2-3 minutes. Electrocardiographic alterations during the first 30 seconds following injection included prolongation of the PR interval, premature atrial contractions and inverted T waves. Pulmonary congestion was a consistent finding at necropsy.

In moderate doses the venom had little effect on the isolated mammalian nerve-muscle preparation. Isolated mammalian cardiac preparations were adversely affected by low doses ( $10^{-3}$  mg/ml) of the venom extract.

#### PLANS FOR FUTURE

To continue the present program of further characterizing the venom and its biological properties, and the mechanism of venom production; to study certain therapeutic measures advised in the treatment of stings by these fish and closely related fish; and to study certain general biological habits of these fish as they are related to divers.

A TAGGING STUDY OF THE FRESHWATER ELASMOBRANCHS  
OF CENTRAL AMERICA

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ASSISTED BY

WORK UNIT NO. NR 104-880

CONTRACT N00014-66-C0161

OBJECTIVES

(a) To demonstrate whether or not the bull shark, Carcharhinus leucas, and the sawfish, Pristis perotteti, move from the Caribbean Sea into Lake Nicaragua, (b) to establish their patterns of movement within the lake and the Rio San Juan which drains it, (c) to determine how long they stay in fresh water once they enter, and (d) to determine whether or not they return to the sea after having been in the lake.

ABSTRACT

Carcharhinus leucas occurs in warm waters around the world, tends to congregate in shallow, brackish water about the mouths of large rivers and to make its way up rivers, sometimes for great distances. This appears to be the case in the San Juan River between Nicaragua and Costa Rica, as well as in Lake Nicaragua, in both of which a sizable population of these sharks occurs. For many years it has been assumed that the sharks in the lake are landlocked by the occurrence of several rapids in the river. It has only been in recent years that this theory has been challenged. A recent paper by my group points out that sharks are common throughout the system and are of the same species throughout, as well as in the sea; that the rapids are navigable by barges and tugs of two feet draught; and that sharks have been seen above and below the major rapids as well as directly in some of the rapids. Although the circumstantial evidence is strong that sharks move up the river into the lake, definitive proof would have to come from sharks tagged at the mouth of the river and recovered in the lake.

The original plan involved conventional tagging, with Peterson disk tags, to be conducted at the three major outlets of the Rio San Juan at Greytown, Nicaragua, Barra del Colorado, Costa Rica (the major outlet) and Samesy Lagoon, Costa Rica; at various points up the river, particularly El Castillo and San Carlos; and at the far end of Lake Nicaragua in the vicinity of Granada. In the second year, sonic tagging was added to follow movements of individual sharks from a boat with a portable hydrophone and receiver. In the third and fourth years, recording shore installations made it possible to monitor the passage of sonic-tagged sharks on a 24-hour basis for nearly two months each year. Sharks have also been followed by attaching a red, hydrogen-filled balloon to the first dorsal fin.

Because of the poor lasting quality of the Petersen disc tags

employed in 1966 and 1967, and the lack of fishing activity in Lake Nicaragua and the upper Rio San Juan, records of movements of sharks up the river were slow in coming. Until the 1968 season, when I shifted to Rototags, there had been only a single recovery recorded any appreciable distance up the river, namely a shark tagged at Colorado and recovered at El Castillo. Likewise, a single shark tagged at San Carlos moved down the river to El Castillo. Otherwise, recoveries were all local, or at short distances up and down the coast from the tagging site.

This year, with 1968 results in, and the 1969 results up to September 1, twelve have gone from El Castillo to the mouth of the river and 8 have gone the full length of the river from San Carlos to the mouth. One of the latter was tagged in San Carlos and recovered one day later at Greytown. In addition, five have gone from Colorado or Samay to El Castillo, and one from El Castillo up into the lake beyond San Carlos.

Most noteworthy, however, were three sharks that went all the way from the Caribbean Sea (Colorado) to Lake Nicaragua at San Carlos. One was a sonic-tagged shark recorded by the monitor at San Carlos, and two were tagged with Rototags. One was tagged in July, 1968 and recovered approximately a year later, and the other was tagged in April, 1969, and recovered in August, 1969.

Also of interest was a shark tagged at San Carlos in July, 1969, and recovered at the other end of the lake in August, 1969. This is our first record of a major movement within the lake.

We continued to tag sawfish (five at Colorado; one at El Castillo; 37 at San Carlos). Until this year, all sawfish recoveries had been at the original tagging site. This pattern continued in 1969, with one exception. One was taken in the Isletas, near Granada, in May, 1969, which had been tagged at San Carlos in June, 1968. The sawfish seem to be more sedentary than the sharks, but they obviously do make major movements.

#### **PLANS FOR FUTURE**

In the concluding season under the contract, conventional tagging, electronic monitoring and balloon tracking will be continued in an attempt to round out the data accumulated to date. Cooperation will be carried on with local government survey personnel to help increase recoveries, which will likely continue to be reported for several years.

#### **CURRENT REPORTS AND PUBLICATIONS**

(a) T. B. Thorson, G. F. Esterberg and J. H. Johnson (1969), Ultrasonic shark tag monitoring system. Technical Report, Office of Naval Research, Department of the Navy, Contract No. N00014-66-C0161, Project NR-104-880.

#### MARINE ECOLOGY

A comprehensive program is being conducted to define the role of biological organisms and systems of organisms in ocean environment. In this program, ecosystems, or the interactions of oceanic biota with both the physical components of the sea and with each other, is being investigated. An understanding of these ecosystems is germane to the three preceding areas of interest.

## THE PHYSIOLOGY OF LUMINESCENT SIGNAL SYSTEMS

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ASSISTED BY A. T. Barnes, M. S. Trinkle and R. Halvorsen

WORK UNIT NO. NR 104-386

CONTRACT N00014-69-A-0200-8006

### OBJECTIVES

To contribute to the understanding of the conditions governing light production in the sea by means of investigations of luminescent multicellular animals at sea and in the laboratory with emphasis upon (a) behavior associated with luminescence, (b) neural control of luminescent organs, and (c) the physiological processes basic to light generation.

### ABSTRACT

Research on several of the principal categories of luminescent systems (specifically coelenterates, arthropods and fish) has continued with the following results:

(1) Luminescent behavior of the mid-water copepod Gaussia has been studied with characterization by means of photomultiplier and image intensifier techniques of the luminescent pattern and its kinetics. Histology of the photophores has been studied as well as their fluorescent spectra.

(2) Neuropharmacology of the photophore system of the midshipman fish, Porichthys has been studied with demonstration of the relevant innervation, and demonstration of adrenergic control.

(3) The neuropharmacology of luminescence control in the marine coelenterate Renilla has been continued and considerably furthered by the use of image intensification methods.

(4) In subsidiary studies adrenergic control has been demonstrated in the railroad worm Phryxothrix and an image intensifier investigation of unit activity in the firefly light organ conducted. While these studies do not bear directly on marine problems they are extremely useful in suggesting lines of approach in studies of the more difficult marine material.

### PLANS FOR FUTURE

Further investigation on shipboard are planned using the image intensifier-video tape system. These will emphasize the study of stimulation and character of luminescence in any suitable crustaceans and fish. In the laboratory the work will emphasize photophore control and function, especially in Porichthys. Attention will focus on the scintillation mechanism in that animal and upon the ultrastructure, with particular reference to the innervation, of the photophore. Gaussia will be studied with particular reference to the antennular light organs, light responses at temperature and oxygen levels corresponding to the depth of capture, and visual responses of the naupliar eye. During the coming summer a few weeks during the firefly season will be spent on image intensification work on the cellular source of luminescence in that most favorable of all preparations for such work, Photuris pennsylvanica.

### CURRENT REPORTS AND PUBLICATIONS

- (a) A. T. Barnes and J. Case (winter, 1970), "Bioluminescence in gaussia princeps." Amer. Zoologist. Definitive manuscript in preparation.
- (b) F. Baguet and J. Case, "Luminescence control in porichthys (teleostei): excitation of isolated photophores." Submitted Biological Bulletin.
- (c) J. Buck, J. Case and F. Hanson (winter, 1970), "Pacemaking and phase-shifting in synchronizing fireflies." Abstract, Biological Bulletin.
- (d) J. Case, et. al. (winter, 1970), "Comparative physiology of neurally controlled luminescence." Abstract, Biological Bulletin.
- (e) J. Case, F. Baguet and J. Burns (winter, 1970), "Photophore control in the midshipman fish, porichthys." Abstract, Amer. Zoologist. Describes work on in situ preparation. Data incomplete.
- (f) F. Hanson, J. Case and J. Buck, "Pacemaking and phase-shifting in synchronizing fireflies." Submitted to Science.

## BIOLOGICAL PREDICTION FROM THE PHYSICAL ENVIRONMENT

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### ASSISTED BY

WORK UNIT NO. NR 083-012

CONTRACT N-C0014-67-A-0103-0014

### OBJECTIVES

The current aim of this project is to collect physical, chemical, and biological data from large areas of the North Pacific Ocean during the spring bloom of phytoplankton over several years. These data will be used to test existing models in their ability to predict timing of phytoplankton blooms as well as the level of production during this period. It is expected that some understanding of the subarctic Pacific will be achieved through this continuing program of observations.

### ABSTRACT

During the past two years, a cooperative program has been developed between the Department of Oceanography, University of Washington (under the Principal Investigator), the Fisheries Research Board of Canada, Nanaimo, British Columbia (T. R. Parsons), and the Faculty of Fisheries, Hokkaido University, Japan (S. Motoda). Fleet Numerical Weather Central, Monterey, provides XBT equipment and tubes at no cost to the contract.

In the first six months of each of 1968 and 1969 and currently in 1970, observations have been made from scheduled merchant vessels (American Mail Line, Ltd.) crossing between Seattle and Japan via a modified great circle route. During 1968, observations were made by ship's officers but biologists have been utilized in subsequent years. Measurements include primary production, chlorophyll *a*, phosphate, nitrate, silicate, temperature, incident radiation, and depth of the mixed layer. Quantitative samples of zooplankton and phytoplankton were taken. In addition, we have participated in several cruises of research vessels where the time and area of operation were pertinent to these studies. Preliminary processing of all data through 1969 has been completed. Zooplankton counts have been made on samples taken during 1969. Counts of phytoplankton are currently in progress.

The Fisheries Research Board of Canada carried out a trans-Pacific cruise on their research vessel, CNAV *Endeavour*, 17 March-1 May 1969, which covered the same cruise track as the merchant vessels. The primary purpose was to investigate the waters of the subarctic Pacific in order to compare the results with theoretical predictions of biological productivity based on data from the merchant vessels and weatherships. In addition, the Canadian group has continued to make oceanographic collections from Weathership "P" (50°N, 145°W) on alternate six-week cruises and has made all of the zooplankton counts from the samples taken from the merchant vessels.



Hokkaido University, Japan, has agreed to send their vessel (*Oshoro Maru*) to Seattle during the present year in cooperation with this study. They will cover large parts of the merchant vessel cruise track at a time when the spring bloom is on the decline or is completely finished in some areas. This information will provide contrast with data from the *Endeavour* which observed mostly the beginning and peak of the bloom.

In collaboration with T. R. Parsons, data from 1969 from both the merchant vessels and from the CNAV *Endeavour* were used to examine the validity of the model by Steele and Menzel to predict primary production in the subarctic Pacific. The form of the relationship is as follows:

$$P_r = \frac{0.24 I_0 C_h}{k} \exp(-2e^{-kZ_m}) - e^{-2} - \frac{rkZ_m}{P_{meh}f(N)}$$

where  $I_0$  is the surface radiation (lys/day),  $C_h$  is the average chlorophyll  $a$  concentration in the mixed layer ( $Z_m$ ),  $k$  is the extinction coefficient,  $P_m$  and  $r$  are the maximum photosynthetic and respiration rates of 0.066 gC/g plant C/hr and 0.07 gC/g plant C/day respectively, as defined by Steele,  $h$  is the hours of daylight and  $f(N)$  is a function of a rate limiting nutrient concentration.

Good agreement was obtained between the calculated primary production and that obtained from  $^{14}C$  measurements if allowance was made for plants having different productive rates and chlorophyll-to-carbon ratios. Data from the merchant vessels were used to show seasonal differences in the primary production and type of primary producer in the area.

#### PLANS FOR FUTURE

We will continue to make use of scheduled merchant vessels and research vessels for obtaining information during the first six months of each year. During 1971, a biologist will accompany each of the crossings between Seattle and Yokohama on American Mail Line, Ltd. vessels. With these data, we will examine the validity of the models to predict primary production not only at different times of the spring but also in different years. The importance of these data will be to see how annual events vary to change either the primary production or the type of primary producer over large areas of the North Pacific Ocean.

Counts from preserved phytoplankton samples provide information not only of seasonal changes in the important species but will also provide the necessary data to check the accuracy of our prediction of the seasonal change in the type of primary producer from the model.

We plan to conduct a trans-Pacific crossing on the RV *T. G. Thompson* following the same route of the merchant vessels. This will provide three successive years of information from a combined program of merchant and research vessels (CNAV *Endeavour*, 1969; *Oshoro Maru*, 1970). The cruise is designed to be carried out during May during the height of the spring bloom in most areas. Acoustical determination of zooplankton distributions will be made.

#### CURRENT REPORTS AND PUBLICATIONS

(a) G. C. Anderson, T. R. Parsons and K. Stephens (1969), "Nitrate distribution in the subarctic Northeast Pacific Ocean." *Deep-Sea Res.*, 16, 329-334.

(b) G. C. Anderson (In Press), "Some aspects of marine phytoplankton studies near the Columbia River, with special reference to a subsurface chlorophyll maximum." In *Bioenvironmental Studies of the Columbia River Estuary and Adjacent Ocean Region*. (Dayton L. Alverson and A. T. Pruter, eds.). U.S. Atomic Energy Commission.

(c) T. R. Parsons and G. C. Anderson (In Press), "Large scale studies of primary production in the North Pacific Ocean." *Deep-Sea Res.*

(d) W. K. Peterson (In Press), "The distribution of pelagic copepods off the coast of Washington and Oregon during 1961 and 1962." In *Bioenvironmental Studies of the Columbia River Estuary and Adjacent Ocean Region*. (Dayton L. Alverson and A. T. Pruter, eds.). U.S. Atomic Energy Commission.

**GULF OCEANOGRAPHY**  
**Bioenergetic Studies of the Gulf of Mexico**

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**ASSISTED BY**

**WORK UNIT NO. NR** 083-036

**CONTRACT** N00014-68-A-0308(0002)

**OBJECTIVES**

(a) To develop a mathematical model expressing the organic energy budgets of the Gulf of Mexico ecosystem, (b) to assess the availability of information presently available to quantify various portions of the model, (c) to initiate studies on the energy content of sediments, suspended and dissolved organic material, as well as the various components of the living system, (d) to initiate metabolic studies on the biological components of the Gulf ecosystem.

**ABSTRACT**

The Gulf bioenergetic studies which began this year have been pursued on three fronts. (a) Published literature as well as unpublished research reports have been scoured for quantitative information of value in the ecosystem analysis. (b) During a cruise in the month of March sediment samples were collected, and biological materials were taken and identified. These materials are being kept frozen for subsequent combustion analysis to provide energy conversion values. (c) Efforts have been made to establish portions of the predictive mathematical model of the Gulf system. The most promising approach to date involves division of the Gulf into a series of quadrates. The equations may, thus, express the energy inputs, internal dynamics, and outflows in respect to each quadrate. Input and outflow values can express the inter-quadrate relationships.

**PLANS FOR FUTURE**

(a) During subsequent cruises samples of sediments, biological materials, dissolved organic matter, and particulate organic matter will be collected and combusted. (b) Respirometry and fecal production studies will be carried out on selected marine organisms to determine energy degradation values. (c) Data on stream discharge and sediment loads will be obtained from the Army Engineers and from the Mexican Government to provide information on the energy input by streams. (d) From equations already on hand and others to be developed continued efforts will be made to develop the first order compartmented analog simulation model of the Gulf.

## **CURRENT REPORTS AND PUBLICATIONS**

None

# ECOLOGICAL STUDIES OF THE FORMATION AND STABILITY OF COMMUNITIES ON SOLID SUBSTRATES

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ASSISTED BY A. O. Flechsig

WORK UNIT NO. NR 083-005

CONTRACT USN 00014-69A-0200-  
6006

## OBJECTIVES

To determine the principles and processes that determine the formation and stability of marine benthic communities.

## ABSTRACT

There are now four "artificial rocks" in position in 40 feet of water. The "rocks" are cubes, 1 meter on a side, constructed of transite boards on angle-iron frames. One of these has been in over two years and the other 3 have been in over a year. Two were put close together to test the effect of pairing; the others are isolated. Among the larger animals appearing at the "rocks", only the 2 sandbass species and the common seastar are resident throughout the year. Their numbers remain astonishingly constant. The other fish and larger invertebrates have all shown considerable changes in abundances but we are beginning to obtain evidence that these changes are repetitive. For example, the scorpionfish that gave so much trouble during Sealab II, start to appear at our "rocks" in April or May and stay there in some numbers until October; one of the large crabs is present in the period February to June and is replaced by spiny lobsters in July to October. Our time lapse camera work has shown that the scorpionfish feed almost entirely at night. In contrast, the schools of perch come to the "rocks" at dawn, feed a bit on and around them, move on and repeat this two or three times during each day.

The "rocks" show considerable similarities. The frequencies of observation and abundances of all the more abundant fish species and the larger invertebrates are independent of "rock" position or whether they are single or in a pair. The relative abundances of all the major groups of smaller invertebrates are independent of the "rock" being considered, and, after the "rock" has been down about 3 months, of its "age". The amount of organic matter, per square centimeter measured as nitrogen, is also independent of position or "age". On all these counts, the "rocks" appear to be samples of the same community.

The samples are, however, not identical. This is particularly well shown by the large brown algae. One of the "rocks" has a heavy growth of Pterogophora plus two plants of Laminaria; the two placed as a pair have large Macrocystis plants on them but no plants of the preceding two species; one large brown alga, Egregia, is present on all three. The fourth "rock" had no large brown algae on it for over a year; some small plants have appeared in the last two months.

The picture that is emerging is of a system that is made up of a limited list of components, some of which are present all or most of the time, others of which appear periodically. All of the components of either type are unlikely to be present at one time in any one example of the system. Although the period of observation is far too short to allow any definitive statements about stability, there is every indication that it is a dynamically stable system. It is interesting that it so rapidly - in certainly less than six months - reaches this state and then maintains it in a changing and physically rigorous environment and with relatively few species involved.

#### PLANS FOR FUTURE

We intend to continue observations on these samples of the system and put down others in different areas to determine what variability is introduced by the surroundings. We have also started field experiments involving removal of some of the larger components or of the community of smaller invertebrates and plants that coat the surfaces. The effects of these removals, and possible later additions, should give us insight into the place in the system of the removed organisms. As soon as sufficiently detailed information is available we will use it in the community simulation computer program already developed.

#### CURRENT REPORTS AND PUBLICATIONS

(a) Fager, Edward W. (1969), "Production of stream benthos: a critique of the method of assessment proposed by Hynes and Coleman (1968)". Limnol. & Oceanog. 14 (5), 766-770.

(b) Fager, Edward W. (1969), "Recurrent group analysis in the classification of Flexibacteria". J. Gen. Microbiol. 58, 179-187.

# COMPARATIVE BEHAVIORAL RESPONSES OF MARINE ORGANISMS TO INCREASE IN HYDROSTATIC PRESSURE

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Florida State University  
Tallahassee, Florida

ASSISTED BY Robert Avent

WORK UNIT NO. NR 083-231/9-29-69 481 CONTRACT N00014-67-A-0235-0002

## OBJECTIVES

(a) To study the effects of increased hydrostatic pressure on various marine organisms, (b) to ascertain whether organic complexity and pressure sensitivity were related phenomena, (c) to ascertain the response of organisms from various habitats to increased hydrostatic pressure, (d) determine whether organisms from one in situ hydrostatic milieu (habitat) were better able to withstand increased hydrostatic pressure than ones from another habitat.

## ABSTRACT

An apparatus has now been designed, constructed, and tested which can reach 15,000psi (deepest habitat pressure in the ocean). Earlier experimentation with the Kylstra apparatus and the prototype of our new apparatus leads us to the following tentative conclusions with reference to pressure of first response and to pressure of inactivation. Experimentation with lethal pressures has not yet been made. The average pressure of first response is 20 higher taxa (classes and orders) is less than the mean pressure of inactivation in most cases. Both responses, when plotted against psi increase in pressure suggest strongly that there is no increase relationship between organic complexity and pressure sensitivity. Plotting the data against habitat of the test animal we find that there is a slight indication that animals from greater depth of habitat are not as sensitive to pressure change than are animals from shallow habitats. Some results are exceptionally interesting; for example, brachyuran crabs are inactivated and killed at a depth of 1900 meters. Jelly-fish are among the least sensitive to pressure (first response and inactivation) whereas sea anemones are among the most sensitive both belong to coelenterata. Salps show both a high pressure of first response and one of the highest pressures of inactivation.

## PLANS FOR FUTURE

(a) Cultured experimentation on animals from all habitats and phyla from diverse habitats to assure statistical validity of results, (b) publication of results, (c) use of DRV for study on animals from deep water, (d) submersion experiments in Mediterranean or Arctic waters in order to eliminate temperature effects, and (e) measure rates of

activity as well as behavioral response.

**CURRENT REPORTS AND PUBLICATIONS**

(a) Menzies, R. J. (1970), Semiannual progress report to ONR.

(b) Avent, Robert (1970) "The Effects of Hydrostatic Pressure on Selected Intertidal and Shallow Water Animals". (M.S. Thesis in Preparation, Florida State University), 97 p.



## GENERAL

**AIBS ADVISORY COMMITTEES ON OCEANIC BIOLOGY AND HYDROBIOLOGY  
TO THE OFFICE OF NAVAL RESEARCH**

**Dr. John R. Olive  
Director, AIBS**

**ASSISTED BY** Donald R. Beem and Mary-Frances Thompson

**WORK UNIT NO. NR** 03

**CONTRACT** N00014-70-A-0140-0903AA

**OBJECTIVES**

The Committees advise Mr. Deane Holt, Oceanic Biology Program Director, on his oceanic and hydrobiology programs. The Oceanic Biology Committee, additionally, reviews proposals.

Consultants to the Oceanic Biology Program are also provided, as required.

**ABSTRACT**

The Committees were not requested to meet during the year.

**PLANS FOR FUTURE**

The AIBS Advisory Committee on Hydrobiology will be discontinued. Its functions will be assumed by the AIBS Oceanic Biology Advisory Panel. This new panel will respond to the following assignments: (a) the scientific evaluation of unsolicited proposals to Oceanic Biology Programs (b) an indepth critique of problem areas in marine biology and biological oceanography as seen by the panel. Panel members need not concern themselves with "mission orientation" or any restrictions on research areas of interest that may be in force at a particular time.

The Panel will be composed of seven members; consultants will be available when needed. A rotating schedule of membership will be established.

The first meeting will be at the Scripps Institution of Oceanography in August 1970. Future meetings will be held in Washington, D. C. and at various scientific institutions.

## AIBS SHARK RESEARCH PANEL

Dr. John R. Olive  
Director, AIBS

**ASSISTED BY** Donald R. Beem and Mary-Frances Thompson

**WORK UNIT NO. NR** 01

**CONTRACT** Nonr-4526

### OBJECTIVES

The Shark Research Panel is concerned with all aspects of the biology of elasmobranch fishes. Its specific objectives are (a) to stimulate, activate, and coordinate basic investigations which deal with the biology and behavior of sharks (b) to assess the shark hazard problem and recommend appropriate protective measures and (c) to advise on the development of better shark deterrents.

### ABSTRACT

Three meetings were held during the contract year. The first was in conjunction with the Panel's biannual open session on Research on Elasmobranch Fishes. Papers were presented by investigators from the United States, the United Kingdom and the Republic of South Africa.

Consultants were invited to the remaining meetings to review the Panel's activities and to consider the need to broaden the scope of its interests to include hazardous marine animals.

Additionally, an *ad hoc* meeting of special consultants was convened, by request, to review a report from the Westinghouse Corporation on the Crown of Thorns (*Acanthaster planci*) problem in the western Pacific and the possible need to organize a conference on the subject.

### PLANS FOR FUTURE

After eleven successful years the AIBS Shark Research Panel program was discontinued on 30 April 1970. At the final meeting the feasibility of organizing a Panel on Hazardous Marine Biological Phenomena was discussed with several scientific and administrative consultants. This panel, which would be composed of three subpanels: (1) Venomous and Poisonous Marine Animals (2) Unusual Marine Phenomena (3) Sharks and Other Predacious Marine Animals, is now under consideration.

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